Investigation of traffic and safety behavior of pedestrians while talking on mobile phone

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Abstract

The objective of this paper is to investigate the impact of hand-held cell phone conversation on pedestrians' traffic and safety behavior, when crossing signalized intersections. An outdoor-environment experiment, through video recording, was conducted in real road conditions, in three signalized intersections at the center of Athens in order to compare the behavior of distracted and non-distracted pedestrians. Multiple linear regression models were developed to define the influence of cell phone distraction on pedestrians' speed. Furthermore, binary logistic regression models were developed to determine the relationship between cell phone distraction and pedestrians' safety characteristics in terms of near misses. The results of the developed statistical models demonstrated that distraction caused by hand-held cell phone conversation had a negative impact on pedestrians' main traffic and safety characteristics as mobile phone use not only decreases pedestrians' speed but also increases their probability of being involved in a road crash with an oncoming vehicle.

Keywords: distraction, mobile phone, pedestrian, behavior, safety, intersection

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1. Introduction

Pedestrians, pedal cyclists and powered two-wheeler riders are considered vulnerable road users (VRUs), as they are prone to a high risk of injury in the event of vehicular collision [1]. Based on the latest global assessment of road safety, the World Health Organization (WHO) indicates that VRUs account for more than half of all road fatalities. Specifically, pedestrians represent 23% of total road fatalities worldwide [2]. In 2019, there were 145 pedestrian fatalities due to road crashes in Greece, which account for 21% of all road fatalities. Since 2017, a slight increase in pedestrian fatalities, from 16% to 21% of total road fatalities has been recorded [3]. However, these numbers may be even higher as pedestrian crashes including pedestrian falls due to poor quality of pavements or the actions of other road users are heavily under-reported in police crash statistics [4].

It is noteworthy that pedestrians' actions and behavior may account for 15% of pedestrian road fatalities [5]. An important factor that needs to be investigated is the correlation of mobile phone use and pedestrian road crashes. It is a fact that technology is constantly evolving and the use of mobile phones is an integral part of the daily life of most citizens. This broad expansion of mobile phones has resulted in an increasing number of pedestrians who use mobile phones in their regular traffic activities by the roadside or even when crossing the street. Based on the results of the DEKRA Accident Research, which was conducted in six major European capitals, it was found that a significant proportion of pedestrians crossing the street made use of their mobile phone (17%) [6]. Mobile phone distraction is a quite common phenomenon especially for young pedestrians. An observational study related to the crossing behavior of students near four major schools in Germany revealed that about 10.5% of students were looking at their mobile phone or typing while crossing the street [7]. Another study carried out in the United States using data for the period 2004-2010, indicated that pedestrian injuries related to mobile phone use were higher for males and young pedestrians under 31 years old [8].

The results of an outdoor-environment experiment among 28 college student pedestrians showed that mobile phone distractions cause different levels of impairment to pedestrians' crossing performance, with the greatest effect from text distraction, followed by phone conversation distraction. Regarding the phone conversation distraction, it was also demonstrated that pedestrians crossed the street at a lower average speed [9]. Hyman et al. have also found similar findings in a study investigating the impact of phone conversation in 2010 [10]. Another observational field survey in three Sydney suburbs showed that crossing speed was lower for both male and female distracted pedestrians compared to pedestrians who crossed without using a mobile phone. Moreover, it was concluded that talking on a mobile phone is associated with cognitive distraction that may undermine pedestrian safety [11].

Based on the above, the objective of this paper is to investigate the impact of hand-held cell phone conversation on pedestrians' traffic and safety behavior, when crossing signalized intersections. Specifically, this paper attempts to explore the differences between the behavior of distracted and non-distracted pedestrians.

2. Data collection

In order to achieve the objectives of the present research, an experimental process through video recording was conducted in real road conditions, in three signalized intersections in the center of the capital of Greece, Athens, in spring 2019. The selection of the streets for the experiment and consequently the selection of the pedestrian crossings were based on the high pedestrian volumes typically found in the area, ensuring sufficient sample size, and the presence of a pedestrian traffic light on each pedestrian crossing. Taking into consideration these criteria, the locations chosen for this experiment were the following:

- Pedestrian crossing on Akadimias Street in the intersection with Ippokratous Street (A)
- Pedestrian crossing on Ippokratous Street in the intersection with Akadimias Street (B)
- Pedestrian crossing on Skoufa Street in the intersection with Filikis Eterias Square (C)

Figure 1: Overhead views of the three selected pedestrian crossings.

Regarding the experiment's video recording, it should be mentioned that it was conducted during daylight hours and clear weather conditions. For each signalized pedestrian crossing, data were collected through one half-hour video recording on a weekday (3:30 pm - 4:00 pm) and through one half-hour video recording on the weekend (1:00 pm - 1:30 pm) as peak hours were examined on both cases. The camera was set up in such way so as the observer was able to easily identify and list each pedestrian's distraction type while recording as the entire crossing and pedestrian traffic signals were visible during each recording. Three hours of video were collected in total and subsequently analyzed, resulting in the observation of several pedestrians and their demographic, traffic and safety characteristics. The data derived from the videos are the following:

- Pedestrian distraction (texting or web-surfing on mobile phone, talking on the phone, listening to music using headphones, no distraction).
- Pedestrian gender (male, female)
- Pedestrian age group estimate (child: 0-17, young: 18-34, middle: 35-64, old: 65+)
- Length and width of pedestrian crossing
- Crossing time
- Pedestrian speed
- Number of road lanes
- Pedestrian volume (number of pedestrians crossing the street at the same time)
- Pedestrian was accompanied by someone else (yes, no)
- Pedestrian traffic light (green, red)
- Trajectory while crossing the street (direct, not direct)
- Conflict with other pedestrian (yes, no)
- Illegal vehicle passing (yes, no)
- Vehicle on crossing (yes, no)
- Weekday
- Waiting time for pedestrian green light
- Near miss - temporal headway between pedestrian and vehicle less than 2 seconds (yes, no)

As can be observed in Table 1, among 2,280 pedestrians, 142 were texting or surfing the Internet, 113 were talking on their mobile phone, 124 were listening to music using headphones while 1,901 were non-distracted. Texting or web-surfing was the most common distraction activity among the pedestrian sample. The results of the investigation of traffic and safety behavior of pedestrians while texting or web-surfing have already been published in a research paper by Ropaka et al. in 2020 [12].

Table 1: Summary statistics for pedestrian observation regarding distraction

Distraction	Count	Percentage
Texting or web-surfing	142	6.2%
Music (headphones)	124	5.4%
Talking	113	5.0%
No distraction	1,901	83.4%
Total	**2,280**	**100.0%**

3. Statistical Analysis

Microsoft Excel and IBM SPSS Statistics (version 21) were used for the analysis of the data obtained from the video recordings. Regarding the statistical analyses, multiple linear regression and binary logistic regression models were developed. The basic equation of the multiple linear regression model is the following:

$$Y_i = \beta_0 + \beta_1 * X_{1i} + \ldots + \beta_v * X_{vi} + \varepsilon_i \quad (1)$$

The accuracy of the linear regression model was assessed through the coefficient of determination R squared (R^2) which shows the percentage of the variability of the dependent variable Y explained by the independent variables X. R^2 takes values between zero and one, with one indicating that the dependent variable is fully explained by the independent variables.

The dependent variable of the linear regression model must be continuous. However, in some cases, the dependent variable may be categorical and discrete outcome models should be applied. When the discrete outcomes of the dependent variable are two, binary logistic regression could be an appropriate kind of statistical model. The best fitting model that describes the linear relationship between a dichotomous dependent variable and a number of explanatory variables is pursued.

If Equation 2 gives the "utility function", then the probability P is given by Equation 3:

$$U=\beta_0+ \beta_1 * X_1 + \ldots + \beta_v * X_v \quad (2)$$
$$P=e^U/ (e^U+1) \quad (3)$$

Most of the tests for goodness of fit of a model are carried out by analyzing residuals. However, residuals cannot be used as a test for goodness of fit of the model for a binary outcome variable. In this case, the goodness of fit of the model can be assessed with the Hosmer & Lemeshow Test [13]. The output of this test is a chi-squared and a p-value. A p-value higher than 0.05 indicates a good fit and an acceptable model. For more in-depth explanations of the two modelling approaches described in this section and related tests such as the t-test and the Wald test, the reader can refer to [14].

4. Results

A high number of regression model tests were carried out for various combinations of variables (including different variable forms such logarithmic or square forms of some variables). The best combination of variables was the one with adequate number of statistically significant variables. Initially, a linear regression model was developed for the logarithm of pedestrian speed including distraction caused by hand-held phone conversation as one of the independent variables. The results of this model are presented in Table 2.

Table 2: Statistical model for pedestrian speed including distraction as independent variable

Independent Variables	β_i	t	Sig.
(Constant)	0.150	6.071	0.000
Distractionhand-yes	-0.021	-2.037	0.042
Gender-male	0.023	2.845	0.005
Age	-0.034	-6.992	0.000
Accompanied-yes	-0.060	-6.266	0.000
Trajectory-direct	0.029	3.160	0.002
Pedestrian light-green	-0.057	-6.125	0.000
Pedestrian volume	-0.002	-3.302	0.001
Number of lanes	0.013	7.434	0.000
Adjusted R^2		**0.363**	

Based on the results of the statistical model appeared on Table 2, it can be clearly observed that the distraction caused by hand-held mobile phone conversation decrease the average pedestrian speed. However, including "distraction" as one of the independent variables in the statistical models reveals general results focused on the traffic characteristics of both distracted and non-distracted pedestrians, which was not the primary objective of this study. Therefore, a different approach was chosen. More specifically, the selected approach involved calibrating statistical models separately for distracted and non-distracted pedestrians. To that end, the independent variables should be the same for each one of the developed models with the same dependent variable in order to ensure meaning comparisons of the coefficients between the models for the two groups of pedestrians (i.e. distracted and non-distracted). The dependent variables of the statistical models are the logarithm of pedestrian speed (continuous) and near miss (binary: yes or no).

Table 3: Statistical models for pedestrian speed

	Distracted Pedestrians			Non-Distracted Pedestrians		
Independent Variables	**β_i**	**t**	**Sig.**	**β_i**	**t**	**Sig.**
(Constant)	0.196	5.517	0.000	0.232	13.067	0.000
Conflict-yes	-0.044	-1.749	0.083	-0.032	-2.491	0.013
Age	-0.030	2.261	0.026	-0.034	-5.841	0.000
Accompanied-yes	-0.068	1.940	0.055	-0.063	-5.759	0.000
Pedestrian volume^2	$-7.255*10^{-5}$	2.728	0.007	$-7.831*10^{-5}$	-6.226	0.000
Adjusted R^2	**0.179**			**0.243**		

Based on the results of the models appeared on Table 3, it can be observed that the independent variables affect similarly the speed of distracted and non-distracted pedestrians, as the signs of the β coefficients are the same in both cases. More specifically, results indicate for both models the following:

- The negative sign of "Conflict" variable shows that if a conflict occurs between the examined and another pedestrian, pedestrian speed decreases.
- The variable "Age" has a negative relationship with the dependent variable, indicating that as pedestrian age increases, the speed of the pedestrian decreases.
- The negative sign of "Accompanied" variable demonstrates that if someone else accompanies the examined pedestrian, pedestrian speed decreases.
- Pedestrian speed is lower for higher pedestrian volumes.

In order to complement the results of the statistical models and visualize the influence of the examined explanatory variables on the speed of distracted and non-distracted pedestrians, sensitivity analysis was also conducted. As it can be observed in Figure 2, in case of non-accompanied pedestrians and without conflict among examined pedestrians, for all age groups, non-distracted pedestrians present higher speeds than distracted pedestrians regardless of the pedestrian volume, indicating clearly that distraction due to hand-held phone conversation leads to a reduction in pedestrians' speed.

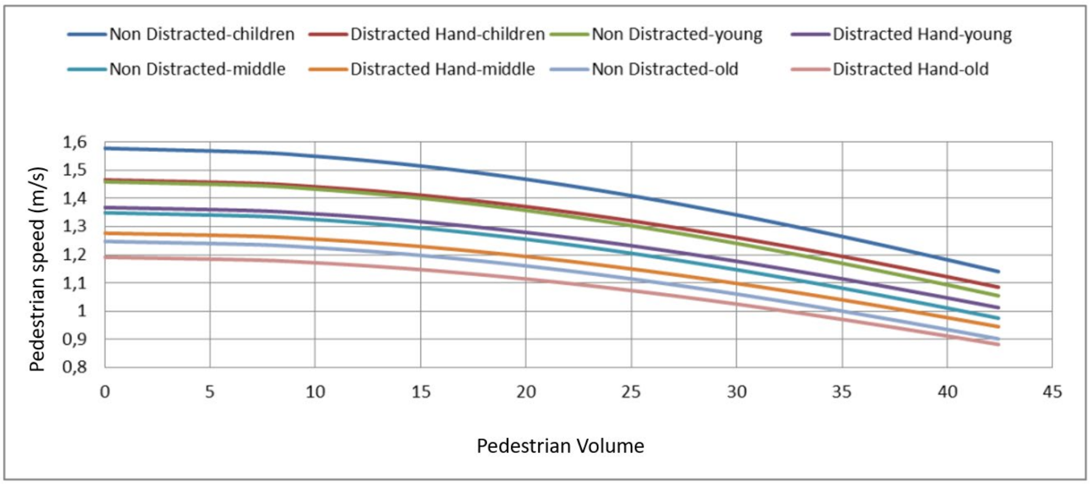

Figure 2: Pedestrian speed to pedestrian volume (non-accompanied pedestrians, no pedestrian conflict)

The relationship between explanatory variables and the probability of a near miss to occur was explored using binary logistic regression. In these binary logistic regression models, the occurrence of a near miss is the dependent variable and it takes two values (0: no near miss and 1: near miss happened). The explanatory variables are the day of the week, the existence of a vehicle on the crossing, the sign of the pedestrian traffic light, the crossing length and the pedestrian volume divided by the crossing length. The respective results are shown on Table 4.

Table 4: Statistical models for near misses

	Distracted Pedestrians			Non-Distracted Pedestrians		
Independent Variables	**β_i**	**Wald**	**Sig.**	**β_i**	**Wald**	**Sig.**
Weekend	3.458	4.641	0.031	1.311	2.773	0.096
Vehicle on crossing-no	-3.989	8.201	0.004	-2.437	8.518	0.004
Red pedestrian light	2.514	5.075	0.024	2.119	6.620	0.010
Ped.Volume/Cross.Length	-0.654	3.857	0.050	-0.876	15.152	0.000
Crossing Length^2	-0.040	7.327	0.007	-0.044	12.066	0.001
Hosmer & Lemeshow Test		**0.996**			**0.638**	

The p-value of Hosmer & Lemeshow Test for goodness of fit is higher than 0.05 indicating that one cannot reject the null hypothesis of the test for both models, which means that these models can be considered as acceptable. The results indicate for both models the following:

- The positive sign of the variable “weekend” shows that there is an increase in the probability of a near miss on weekends.
- There is a decrease in the probability of a near miss when there is no vehicle on the pedestrian crossing.
- Both distracted and non-distracted pedestrians who started walking through the pedestrian crossing when the pedestrian traffic light was red present higher probability of a near miss.
- The sign of pedestrian volume divided by the pedestrian crossing length is negative indicating that an increase in this variable leads to lower probabilities of a near miss.
- The probability of a near miss is higher for pedestrian crossings with lower crossing length.

Two additional sensitivity figures have been developed in order to better understand the influence of the independent variables to the probability of a near miss occurrence (Figures 3 and 4).

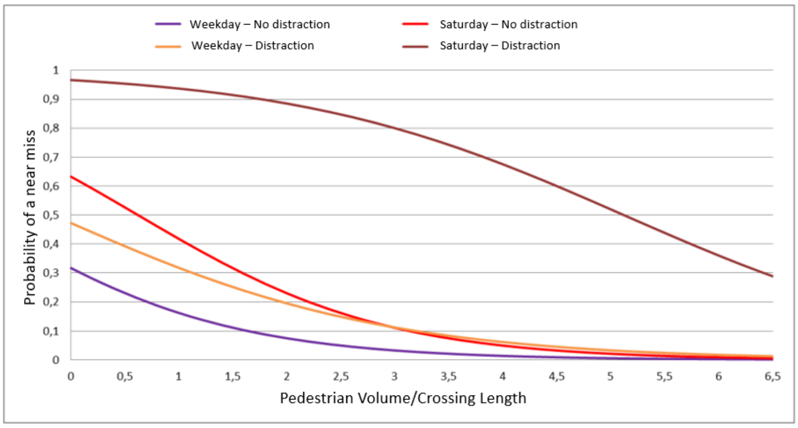

Figure 3: Probability of a Near Miss to Pedestrian Volume/Crossing Length (Vehicle on crossing, Red Pedestrian Traffic Light)

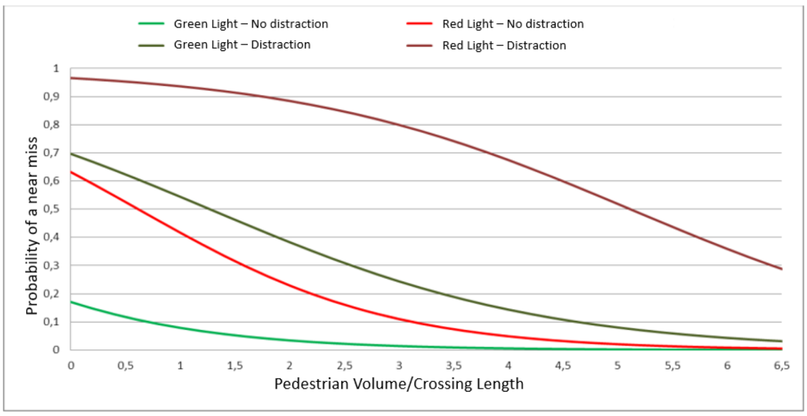

Figure 4: Probability of a Near Miss to Pedestrian Volume Crossing Length (Weekend, Vehicle on crossing)

Based on these figures, it can be observed that distracted pedestrians are most likely to be involved in a near miss on weekends when there is a vehicle on the crossing and the pedestrian traffic light is red. Moreover, on weekends, when there is a vehicle on the pedestrian crossing, distracted pedestrians are more likely to get involved in a near miss compared to non-distracted pedestrians regardless of whether they are crossing the road legally or not.

5. Discussion

Mobile phones are integral to contemporary daily life and their use is growing rapidly as well. For this reason, it is important to investigate the impacts of distracted walking on pedestrians' traffic and safety behavior. Many studies have been carried out aiming to identify the hazards of distracted driving, however, not much emphasis has been placed in studies dealing with the investigation of distracted walking. This study used data derived from an experimental process through video recording, which was conducted in three signalized intersections in the center of Athens, and the results of this paper shed light to the factors that affect the behavior of distracted and non-distracted pedestrians. The analyses pointed out distraction caused by hand-held cell phone conversation had a negative impact on pedestrians' main traffic and safety characteristics as mobile phone use not only decreases pedestrians' speed but also increases their probability of being involved in a road crash with an oncoming vehicle.

To counter the negative impacts of distracted walking, various measures and strategies should be implemented. A type of restriction on walking while using a mobile phone (as compared to the driver mobile phone prohibition) might be foreseen in busy roads where road collisions involving pedestrians are a frequent phenomenon. Moreover, mobile applications warning pedestrians that they are moving towards a pedestrian crossing or that a vehicle is approaching them could be developed. Furthermore, engineering solutions in the design of road crossings and public places (e.g. green and red lights on the ground) may also enhance distracted pedestrians' safety. Regarding further investigation into this topic, it would be highly interesting to expand this experiment in a larger sample of pedestrians and signalized intersections located in different areas, and to carry out a comparative analysis to identify which pedestrians incur higher risks. Lastly, it would be useful to conduct the same experiment during the nighttime in order to find out the differences in pedestrians' behavior as well as examine other factors that could possibly affect them, such as traffic volume.

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